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# (54) VARIABLE-PITCH DEVICE AND WIND TURBINE HAVING SAME

VORRICHTUNG MIT VERSTELLBAREM NEIGUNGSWINKEL UND WINDTURBINE DAMIT

DISPOSITIF À PAS VARIABLE ET ÉOLIENNE DOTÉE DE CELUI-CI

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EP 3 460 233 B1

## Description

### FIELD

**[0001]** The present disclosure relates to the technical field of wind power generation, and in particular to a pitch apparatus of a wind turbine and a wind turbine having the pitch apparatus.

### BACKGROUND

**[0002]** A wind turbine is a large power generator apparatus, which converts wind energy into electric energy by a rotation of an impeller. In the wind turbine, a pitch apparatus is for adjusting a blade angle according to a change of a wind speed, so as to control an absorption of the wind energy by the impeller.

**[0003]** Specifically, during a normal operation of the wind turbine, and in a case that the wind speed exceeds a rated wind speed of the wind turbine, the blade angles are controlled to be within a range from 0° to 30° by the pitch apparatus so as to control an output of the wind turbine, thereby guaranteeing that a speed of the impeller is limited in a rated range. In addition, parking of the wind turbine may be achieved, for example, by the pitch apparatus adjusting the blade to be in a feathering position of 90°.

**[0004]** Figure 1 shows a schematic diagram of a pitch apparatus according to the conventional technology. Figure 2 shows a partial sectional side view of the pitch apparatus according to Figure 1. As shown in Figures 1 and 2, the pitch apparatus includes a pitch bearing 2. The pitch bearing 2 includes a bearing inner race 21 and a bearing outer race 22. A wheel hub 1, which serves as a base body of the wind turbine, is fixedly connected to the bearing inner race 21 of the pitch bearing 2 by a wheel hub connection bolt 7. A blade 6 of the wind turbine is fixedly connected to the bearing outer race 22 of the pitch bearing 2 by a blade connection bolt 8. A transmission belt 3 passes through a driving mechanism 4, a tensioning wheel 31 and a transmission belt pre-tensioning device 32 and is connected to an outer circumferential cylinder surface of the bearing outer race 22 of the pitch bearing 2 with tension. When it is required to perform a pitch operation, the driving mechanism 4 drives the transmission belt 3, so that the bearing outer race 22 of the pitch bearing 2 and the blade 6 of the wind turbine are driven to rotate in relative to the bearing inner race 21 of the pitch bearing 2 and the wheel hub 1 of the wind turbine, so as to achieve a pitch of the blade. International patent publication WO 2013/156497 A1 relates to an adjusting device for a rotor blade (pitch drive) of a rotor of a wind turbine. The wind turbine comprises a tower, a nacelle rotatably supported on the tower, a drive train arranged in the nacelle, and a rotor. The rotor is arranged on the drive train and comprises a hub and at least one rotor blade rotatably supported on the hub. The blade adjustment of a wind turbine is used for power control and to shut down the system. By adjusting the angle of attack of the rotor blade, the area of the rotor blade against which wind flows can be varied, and thus the power transferred from the wind to the drive train of the wind turbine is changed. In order to guarantee the function of a wind turbine, a blade angle adjustment of approximately 100° is required. The adjusting device comprises a belt transmission having a drive and comprises at least one belt.

**[0005]** However, the pitch apparatus according to the conventional technology may suffer from a failure caused by a low safety factor of the pitch bearing races, a low safety factor of the pitch bearing, a low safety factor of the wheel hub connection bolt and a low safety factor of the transmission belt.

### SUMMARY

**[0006]** In order to addresses the above issues of the conventional technology, a pitch apparatus of a wind turbine and a wind turbine having the pitch apparatus are provided in the present disclosure. The pitch apparatus can improve safety factors of components of the pitch apparatus and a safety performance of the pitch apparatus.

**[0007]** According to an aspect of the present disclosure, a pitch apparatus of a wind turbine is provided. The wind turbine may include a wheel hub and multiple blades. The pitch apparatus may include a pitch bearing, a transmission element, a connection plate and a driving mechanism for driving the transmission element. The pitch bearing includes a bearing inner race and a bearing outer race, where the bearing inner race is fixedly connected to the blade, the bearing outer race is fixedly connected to the wheel hub, the transmission element is driven by the driving mechanism drives the blade and the bearing inner race to rotate in relative to the wheel hub. The connection plate comprises the following elements arranged in a radial direction: an inner circumferential portion; an outer circumferential portion; and a middle transition portion connecting the inner circumferential portion and the outer circumferential portion. The transmission element is arranged on the outer circumferential portion of the connection plate and an axial thickness of the middle transition portion is less than an axial thickness of the outer circumferential portion. The connection plate is arranged between the bearing inner race and the blade, or the connection plate is arranged on a periphery of the blade root of the blade, wherein the connection plate is ring-shaped or partially ring-shaped, and the inner circumferential portion is fixed to the periphery of the blade root of the blade

**[0008]** According to an aspect of the disclosure, a wind turbine is provided. The wind turbine includes the pitch apparatus described above.

**[0009]** According to the pitch apparatus of the wind turbine provided in the embodiment of the present disclosure, in a case that the blades have a same specification,

by increasing a size of a pitch bearing, that is for performing an inner race pitch through an inner race connection plate, a pitch diameter of the bolt increases accordingly, the number of bolts increases, and a distribution diameter of the transmission element increases, so that an anti-load capacity of the blade root increases, a load on a single bolt and a load on the bearing roller decrease.

**[0010]** In this case, according to the pitch apparatus of the wind turbine provided in the embodiment of the present disclosure, a load level of an ultimate bending moment for a blade root increases, a safety factor of the pitch bearing and a safety factor of the connection bolt increase, a safety factor of the pitch bearing inner race, a safety factor of the pitch bearing outer race and a safety factor of the transmission element increase.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0011]** The above objectives and/or other objectives and advantages of this disclosure will be described clearly hereinafter in conjunction with the drawings and the embodiments.

Figure 1 shows a schematic diagram of a pitch apparatus according to the conventional technology;

Figure 2 shows a partial sectional side view of the pitch apparatus according to Figure 1;

Figure 3 is a perspective view of a pitch apparatus according to a first embodiment of the present disclosure;

Figure 4 is a partial sectional view of the pitch apparatus according to the first embodiment of the present disclosure;

Figure 5 is a perspective view of a connection plate of the pitch apparatus according to the first embodiment of the present disclosure;

Figure 6A is a partial sectional view of a pitch apparatus according to a second embodiment of the present disclosure;

Figure 6B is a plan view of a connection plate of the pitch apparatus according to the second embodiment of the present disclosure;

Figure 6C is a front sectional view of the connection plate of the pitch apparatus according to the second embodiment of the present disclosure;

Figures 7A and 7B are partial sectional views of a pitch apparatus according to a third embodiment of the present disclosure;

Figures 8A and 8B are partial sectional views of a pitch apparatus according to a fourth embodiment of the present disclosure; and

Figures 9A and 9B are partial sectional views of a pitch apparatus according to a fifth embodiment of the present disclosure.

## DETAILED DESCRIPTION OF EMBODIMENTS

**[0012]** In a pitch apparatus according to the conventional technology, a blade is connected to a bearing outer race of a pitch bearing, so that a solution of an outer race pitch is adopted. Therefore, there is an issue of a low safety factor of the pitch apparatus. In order to address the above issue, a solution of an inner race pitch, which is different from the outer race pitch method of the conventional technology, is adopted in the present disclosure, so that the blade is connected to the bearing inner race of the pitch bearing. The blade and the bearing inner race are driven by a transmission element (e.g. a transmission belt) to rotate in relative to the bearing outer race and a wheel hub at a predetermined angle, so as to achieve a rotation pitch of the blade. Compared with the solution of the outer race pitch according to the conventional technology, in a case that the blades have a same specification, that is, a diameter of a blade root is unchanged, since the blade root is connected to the bearing inner race, a size of the bearing inner race and a size of the bearing outer race should be increased, a diameter of a flange for connecting the wheel hub should be increased accordingly, and a pitch diameter of a bearing roller, a distribution diameter of a transmission element and a diameter of a connection bolt should also be increased accordingly, thereby improving safety factors of components of the pitch apparatus and improving a safety performance of the pitch apparatus.

**[0013]** For the solution of the inner race pitch provided in the present disclosure, multiple exemplary embodiments that achieve a connection between the blade and the bearing inner race and a connection between the blade and the transmission element are provided in the specification. Hereinafter, the specific embodiments of the present disclosure are described in detail in conjunction with the drawings.

### First embodiment

**[0014]** Figure 3 is a perspective view of a pitch apparatus according to a first embodiment of the present disclosure. Figure 4 is a partial sectional view of the pitch apparatus according to the first embodiment of the present disclosure. Figure 5 is a perspective view of a connection plate of the pitch apparatus according to the first embodiment of the present disclosure.

**[0015]** As shown in Figures 3 and 4, a pitch apparatus is provided in a first embodiment of the present disclosure. The pitch apparatus includes: a pitch bearing 2, a

connection plate 10, a driving mechanism 4 and a transmission element. The pitch bearing 2 includes a bearing inner race 21, a bearing outer race 22 and a rolling element 23 (e.g., a ball or a pin roller) arranged between the bearing inner race 21 and the bearing outer race 22. The bearing outer race 22 is sleeved on a periphery of the bearing inner race 21, and can rotate in relative to the bearing inner race 21. The bearing outer race 22 may be fixedly connected to a wheel hub 1 by a bearing outer race connection bolt 7. The bearing inner race 21 may be fixedly connected to a blade 6 by a bearing inner race connection bolt 8. The connection plate 10 is located between the bearing inner race 21 and the blade 6.

**[0016]** A transmission manner between the driving mechanism 4 and the transmission element may be a belt transmission, a chain transmission, a winching transmission, a steel rope transmission, etc. Correspondingly, the transmission element may be a transmission belt, a transmission chain, a steel rope, etc., as long as a driving force can be transferred to the blade 6 to make the blade 6 rotate. Hereinafter, the transmission belt is taken as an example for illustration.

**[0017]** In a case where the pitch apparatus is installed on the wind turbine, the bearing outer race 22 is fixedly connected to the wheel hub 1 of the wind turbine, the connection plate 10 is fixedly connected between the bearing inner race 21 and the blade 6. Specifically, an axial first end of the connection plate 10 is connected to the bearing inner race 21, an axial second end of the connection plate 10 is connected to a blade root of the blade 6. On a position corresponding to a through hole for flange connection of the bearing inner race 21, the connection plate 10 is provided with an axial through holes 14 corresponding thereto (which will be described in detail hereinafter). The bearing inner race connection bolt 8 passes through the through hole of the bearing inner race 21 and the through hole of the connection plate 10 in the sequence listed. Then, the bearing inner race connection bolt 8 is screwed in a threaded blind hole in the blade root of the blade 6, so that the bearing inner race 21, the connection plate 10 and the blade 6 are fixedly connected by fastening a locknut. The driving mechanism 4 is arranged on the wheel hub 1 of the wind turbine. The transmission belt 3 passes over the driving mechanism 4 and is sleeved on a periphery of the connection plate 10. Two ends of the transmission belt 3 is pretensioned to an outer circumferential surface of the connection plate 10 by a pre-tensioning device 32. When it is required to adjust a blade angle of the blade 6, the driving mechanism 4 operates. The transmission belt 3 is driven by the driving mechanism 4, and drives the connection plate 10, the bearing inner race 21 and the blade 6 to rotate a predetermined angle in relative to the bearing outer race 22 and the wheel hub 1, so as to realize a pitch of the blade 6.

**[0018]** In an embodiment of the present disclosure, the driving mechanism 4 consists of a pitch driving gear. The pitch apparatus may further include a tensioning wheel 31. The transmission belt 3 is tensioned to the periphery of the connection plate 10 by the tensioning wheel 31 and the pitch driving gear 4.

**[0019]** As shown in Figures 3 to 5, in an embodiment of the present disclosure, the connection plate 10 is a ring-shaped plate structure. To facilitate an illustration for the structure of the connection plate 10, the connection plate 10 may be divided into an inner circumferential portion 11, an outer circumferential portion 13 and a middle transition portion 12 connecting the inner circumferential portion 11 and the outer circumferential portion 13, which are arranged in a radial direction.

**[0020]** As shown in Figure 5, the inner circumferential portion 11 is provided with multiple first axial through holes 14 extending in an axial direction and evenly distributed in a circumferential direction. The bearing inner race 21 is provided with multiple second axial through holes (which may be threaded holes) corresponding to the multiple first axial through holes 14. Multiple threaded holes corresponding thereto, which may be blind holes, is provided with the blade root of the blade 6. When connecting the bearing inner race 21, the connection plate 10 and the blade 6, the bearing inner race 21, the connection plate 10 and the blade 6 are coaxially aligned, and the threaded holes or the through holes thereof are also coaxially aligned correspondingly in the axial direction. The bearing inner race connection bolt 8 passes through the second through hole of the bearing inner race 21 and the first through hole of the connection plate 10 in the sequence listed, then the bearing inner race connection bolt 8 is screwed in the threaded hole in the blade root of the blade 6, and is fastened by a nut, thereby realizing a fixed connection between the blade 6 of the wind turbine and the bearing inner race 21 of the pitch bearing 2 (as shown in Figures 3 and 4).

**[0021]** In addition, in an embodiment, the bearing outer race 22 is provided with multiple threaded holes or multiple through holes. By the bearing outer race connection bolt 7 passing through the bearing outer race 22 and being fastened to corresponding threaded holes of the wheel hub 1 of the wind turbine, a fixed connection between the bearing outer race 22 and the wheel hub 1 of the wind turbine is realized.

**[0022]** In addition to the manner of arranging the threaded holes on the root of the blade 6, a loop of studs may be pre-embedded on the root of the blade 6, where the studs are arranged on the root of the blade 6 in a circumferential direction. When the blade 6 is connected to the connection plate 10 and the bearing inner race 21, the studs of the blade 6 pass through the first axial through hole 14 of the connection plate 10 and the second axial through hole of the bearing inner race 21, and then is fastened by a nut.

**[0023]** Since the transmission belt 3 is of a certain width, in order to meet installation requirements of the transmission belt 3, a surface axial thickness of the outer circumferential portion 13 of the connection plate 10 that is connected to the transmission belt 3 should be greater

than or equal to a width of the transmission belt 3, therefore, the outer circumferential portion 13 of the connection plate 10 may be formed with a certain thickness. Also, in order to meet strength requirements of a bolt connection between the blade 6 and the bearing inner race 21, a thickness of the inner circumferential portion 11 of the connection plate 10 that is connected to the bearing inner circumferential connection bolt 8 may also be large.

**[0024]** In order to reduce a weight of the connection plate 10 and save a cost, the outer circumferential portion 13 of the connection plate 10 may be formed as a non-complete ring structure. For example, the inner circumferential portion 11 is a complete ring structure, and the middle transition portion 12 and the outer circumferential portion 13 are formed as the non-complete ring structure which is a portion of a ring. Due to that the structure of the connection plate 10 can meet winding requirements of the transmission belt 3, since the pitch angle of the blade 6 is in a range of 0° to 30° during an actual pitch process of the blade 6, and the transmission belt 3 only wind around partial circumference of the connection plate 10 using a winding angle of the transmission belt 3 shown in Figure 3. In the embodiment, the outer circumferential portion of the connection plate 10 is designed as the non-complete ring structure, so as to save a material cost and reduce a weight of the connection plate 10. Apparently, in an actual implementation, the connection plate 10 may also be designed as the complete ring structure based on an actual requirement.

**[0025]** In addition, the middle transition portion 12 may be a spoke structure, in other words, multiple lightening holes 15, which are separated from each other, are arranged in the middle transition portion 12 of the connection plate 10, so as to further reduce the weight of the connection plate 10.

**[0026]** In addition to the above structure, the middle transition portion 12 may be thinner as long as installation requirements and strength requirements can be met, so that an axial thickness of the middle transition portion 12 may be smaller than or equal to an axial thickness of the inner circumferential portion 11, or an axial thickness of the middle transition portion 12 may be smaller than or equal to an axial thickness of the inner circumferential portion 11 and the outer circumferential portion 13, thereby further reducing the weight of the connection plate 10. In this case, the inner circumferential portion 11 and the outer circumferential portion 13 are generally cylindrical. A shape of a cross section that is intercepted in the radial direction of the connection plate 10 may be approximately a shape of "H" or "Z".

**[0027]** In the present disclosure, there are not specific limitations for the radial width and the axial thickness of the portions of the connection plate 10, as long as there is no interference among the connection plate 10, the bearing outer race 22 and the bearing outer race connection bolts 7 in and after the installation process.

**[0028]** When installing the pitch apparatus and the wind turbine according to the embodiment, the following method may be used. First, the bearing outer race 22 is fixedly connected to the wheel hub 1 of the wind turbine by the bearing outer race connection bolt 7. Then, the connection plate 10 is arranged at a right position, and the bearing inner race 21 is fixed connected to the connection plate 10 and the blade 6 of the wind turbine by the bearing inner race connection bolt 8. By such an installation sequence, the interference between the outer race connection bolt 7 and the connection plate 10 can be avoided.

**[0029]** In the exemplary embodiment of the present disclosure, a transmission between the periphery of the connection plate 10 and the transmission belt 3 are performed by friction. Based on the requirement, a corresponding anti-friction processing or a friction enhancement processing may be performed on the outer circumferential surface of the connection plate 10 to change a friction coefficient of a mating surface, so as to meet transmission requirements of different transmission belts and to avoid a slipping risk between the transmission belt 3 and the connection plate 10.

**[0030]** The transmission belt 3 may be a toothed belt or a toothed chain, etc. In a case where the transmission belt 3 is the toothed belt or the toothed chain, a toothed structure may further be arranged on the outer circumferential surface of the connection plate 10, so as to match the toothed belt or the toothed chain.

Second embodiment

**[0031]** Figure 6A is a partial sectional view of a pitch apparatus according to a second embodiment of the present disclosure. Figure 6B is a plan view of a connection plate of the pitch apparatus according to the second embodiment of the present disclosure. Figure 6C is a front sectional view of the connection plate of the pitch apparatus according to the second embodiment of the present disclosure.

**[0032]** As shown in Figure 6A, the pitch apparatus based on the second embodiment of the present disclosure may also include a connection plate. Figures 6B and 6C show schematic structural diagrams of the connection plate of the pitch apparatus according to the second embodiment of the present disclosure. According to the second embodiment of the present disclosure, an arrangement position and a structure of a connection plate 40 change, which is different from the pitch apparatus according to the first embodiment. Except the structure of the connection plate 40 and the blade 6, the structure of the pitch apparatus according to the second embodiment of the present disclosure is the same as the structure of the pitch apparatus according to the first embodiment. Therefore, the description of the same part is omitted, only the parts that are different from the first embodiment are described hereinafter.

**[0033]** As shown in Figures 6B and 6C, in the second embodiment of the present disclosure, the connection

plate 40 may also be a ring-shaped plate and include an inner circumferential portion 41 and an outer circumferential portion 43 and a middle transition portion 42 connecting the inner circumferential portion 41 and the outer circumferential portion 43. The inner circumferential portion 41 of the connection plate 40 is bonded to a position of the blade 6 that is close to a pitch bearing 2. As an example, an inserting groove may be formed on an outer circumferential of a periphery of a blade root of the blade 6, the inner circumferential portion 41 of the connection plate 40 may be inserted into the inserting groove of the blade 6. A bolt hole may be formed on the inner circumferential portion 41. In a case where the inner circumferential portion is inserted into the inserting groove of the blade 6, the connection plate 40 may be pre-embeddedly connected to the inserting groove of the blade root of the blade 6 by the inner race connection bolt 8. A transmission belt 3 is connected to the outer circumferential surface of the connection plate 40 by a pre-tensioning apparatus of the transmission belt, thereby driving a rotation pitch of the driving blade 6.

**[0034]** For a convenience of connecting the connection plate 40 to the outer circumferential of the periphery of the blade root of the blade 6, the connection plate 40 may be formed as multiple arc-segments that joint as a ring or a part of a ring when being installed on the blade root. Figure 6B shows that the connection plate 40 consists of two arc-segment portions. An inscribed angle of each arc-segment is less than or equal to 180 degrees. Preferably, the connection plate 40 may consist of three to six arc-segment portions, so as to facilitate an installation of the connection plate 40.

**[0035]** The multiple arc-segment portions may be inserted into the inserting groove of the blade root of the blade 6 in a radial direction. Preferably, multiple inserting projections 44 are formed on the inner circumferential portion 41 of the connection plate 40, where the multiple inserting projections 44 extend inwardly in a radial direction and are evenly distributed in a circumferential direction. An axial through hole 45, which is for a bolt connection with the blade 6, may be formed on the inserting projection 44. The multiple inserting projections 44 are embedded and connected to the inserting groove of the blade 6 and are fixedly connected to the blade 6 by a bolt.

**[0036]** In the second embodiment, a connection manner between the connection plate 40 and the blade 6 is not limited to what is shown in Figures. Other manners such as a pin connection, a wedge connection, a lip alignment may also be adopted.

**[0037]** Similar to the connection plate 10 according to the first embodiment of the present disclosure, the outer circumferential portion 43 of the connection plate 40 may also not be a complete ring structure as long as installation requirements and strength requirements are met, the axial thickness of the middle transition portion 42 may be thinner and the lightening hole may be formed in the middle transition portion 42, and the like. In addition, a shape of a cross section that is intercepted in the radial direction of the connection plate 40 may be approximately a shape of "H", "Z", "L" or "T".

**[0038]** The shape of the connection plate 40 is not limited to the shapes shown in Figures and described above, as long as the outer circumferential surface of the connection plate 40 can meet the mating requirements of the transmission belt., the installation requirements and the strength requirements

Third embodiment

**[0039]** Figures 7A and 7B show partial sectional views of a pitch apparatus according to a third embodiment of the present disclosure. The pitch apparatus in the third embodiment also includes a connection plate. According to the third embodiment, a connection plate and a blade 6 are an integral structure, which is different from the first embodiment and the second embodiment. That is, an inner circumferential portion and a blade root are integrally formed to be the integral structure. In other words, a projection structure 60, which replaces the connection plate in the first embodiment and the second embodiment, may be integrally formed on an outer circumferential surface of the blade root of the blade 6. Apparently, the projection structure 60 and the outer circumferential surface of the blade root may also be detachable. A transmission belt 3 is connected to an outer circumferential surface of the projection structure by a pre-tensioning device, so as to drive a rotation pitch of the blade 6.

**[0040]** The projection structure 60 may include a radially extending portion extending outwardly in a radial direction from the periphery of the blade root. The transmission belt 3 may be wound around an outer circumferential surface of the radially extending portion. Furthermore, the projection structure 60 may further include an axially extending portion extending in the radial direction from an outer end of the radially extending portion. The transmission belt 3 may be wound around an outer circumferential surface of the axially extending portion.

**[0041]** Similar to the connection plate in the first embodiment and the second embodiment, the projection structure 60 may be ring-shaped or partially ring-shaped, an outer circumferential portion of the projection structure 60 may also be a non-complete ring structure and the lightening hole may be formed in the radially extending portion. The shape of the projection structure 60 may be the same or approximately the same shape as the connection plate 10 shown in Figure 5 or the connection plate 40 shown in Figure 6B, which are not described in detail herein.

**[0042]** As shown in Figure 7A, materials that are the same as materials of the blade may be used to form the projection structure 60 in a manufacture process of the blade 6. As shown in Figure 7B, in a case where the material of the blade 6 can not meet the strength requirements of a pitch operation, other suitable materials may be selected for manufacturing the blade root and the projection structure 60, thereby meeting the strength re-

quirements.

**[0043]** The shape of the projection structure 60 in the present embodiment is not limited to the shapes shown in Figures, as long as the outer circumferential surface of the projection structure 60 can meet mating requirements of the transmission belt. In order to meet transmission requirements of different transmission belt, a corresponding anti-friction processing or a friction enhancement processing may be performed on the outer circumferential surface of the projection structure 60 to change a friction coefficient of a mating surface. Optionally, the transmission belt 3 may be a toothed belt or a toothed chain. In addition, a toothed structure may be arranged on the outer circumferential surface of the projection structure, so as to match the toothed belt or the toothed chain.

Fourth embodiment

**[0044]** Figures 8A and 8B show partial sectional views of a pitch apparatus according to a fourth embodiment of the present disclosure. According to the fourth embodiment of the present disclosure, there is no connection plate, which are different from the first embodiment and the second embodiment according to the present disclosure, and a transmission belt 3 is directly connected to a blade root of a blade 6 by a pre-tensioning device, thereby driving a rotation pitch of the blade 6, which is similar to the third embodiment of the present disclosure. Unlike the third embodiment, a projection structure 60 is not formed on the outer circumferential of the blade root of the blade 6, and the transmission belt is directly wound around the periphery of the blade root.

**[0045]** In order to further limit a mating area of the blade 6 and the transmission belt 3, a groove 601 may be arranged at a mating portion of the blade root and the transmission belt as shown in Figure 8B, or other similar manners may be adopted, so as to stably arrange the transmission belt 3 in the groove 601 and to prevent a displacement of the transmission belt 3 in an axial direction.

**[0046]** Similarly, a corresponding anti-friction or a friction enhancement processing may be performed on a mating surface of the blade 6 and the transmission belt 3 to change a friction coefficient of the mating surface. The transmission belt 3 may be a toothed belt or a toothed chain. In addition, a toothed structure may be arranged on the outer circumferential surface of the blade 6 to match the toothed belt or the toothed chain.

Fifth embodiment

**[0047]** Figures 9A and 9B show partial sectional views of a pitch apparatus according to a fifth embodiment of the present disclosure. A bearing inner race 21 of a pitch bearing 2 outwardly extends beyond a bearing outer race 22 for a predetermined length in an axial direction, which is different from the previous embodiments. In other words, An extending portion 210 or 310 is formed on the bearing inner race 21 in an axial direction facing a blade 6, an axial through hole in the bearing inner race 21 also extends and passes through the extending portion 210 or 310, so that a bearing inner race connection bolt 8 may pass through the bearing inner race 21 and the extending portion 210 or 310 and then is fastened to the blade 6, thereby fixedly connecting the blade 6 and the bearing inner race 21.

**[0048]** A transmission belt 3 is connected to an outer circumferential surface of the extending portion 210 or 310 of the bearing inner race 21 by a pre-tensioning device to drive a rotation of the bearing inner race 21. A rotation pitch of the blade 6 is driven by the bearing inner race 21.

**[0049]** As shown in Figure 9A, the extending portion 210 may extend a predetermined length in the axial direction from the bearing inner race 21, where a shape of the extending portion is generally cylindrical. The predetermined length is greater than a width of the transmission belt 3. For matching with the transmission belt 3, a corresponding processing may be performed on the outer circumferential surface of the extending portion 210. For example, an anti-friction processing or a friction enhancement processing may be performed on the outer circumferential surface. The transmission belt 3 may be a toothed belt or a toothed chain. Therefore, a toothed structure may be formed on the outer circumferential surface so as to be engaged with the toothed belt or the toothed chain.

**[0050]** The extending portion 310 in Figure 9B is different from the extending portion 210 in Figure 9A. The extending portion 310 further includes a projection structure on the basis of the extending portion 210 shown in Figure 9A, so as to further increase a pitch diameter of the transmission belt 3.

**[0051]** As shown in Figure 9B, the extending portion 310 may include an axially extending portion 312 and a projection structure, and the projection structure is formed on an outer circumferential of the axially extending portion 312.

**[0052]** The projection structure may include a radially extending portion 314 extending outwardly in a radial direction. In this case, the transmission belt 3 may be wound around an outer circumferential surface of the radially extending portion 314. Furthermore, the projection structure may also include a transmission element installation portion 316 extending outwardly in an axial direction from an outer end of the radially extending portion 314, where the transmission belt 3 may be wound around an outer circumferential surface of the transmission element installation portion 316. The projection structure may be formed integrally with the axially extending portion 312, or may be formed as a single component that is inserted into the outer circumferential of the axially extending portion 312, which adopts a similar manner as the connection plate 40 according to the second embodiment. For example, an inner circumferential of the radially extending portion 314 is provided with the inserting

projection extending inwardly in the radial direction, a corresponding inserting groove may be formed on the outer circumferential of the axially extending portion 312, so that the projection structure is bonded to the radially extending portion 314 by matching the inserting projection and the inserting groove. Similar to the structure of the connection plate 40 in the previous embodiments, a shape of a cross-section of the projection structure may be a shape of "-", "T" or "L". The projection structure may be ring-shaped or partially ring-shaped. Further, a lightening hole may be formed on the radially extending portion 314.

**[0053]** In other words, the structure of embodiment shown in Figure 9B may be acquired by forming an integral structure having the connection plate 10 and the bearing inner race 21 according to the first embodiment of the present disclosure. In other words, the pitch apparatus shown in Figure 9B may also include a connection plate 80, where the connection plate 80 and the bearing inner race 21 are formed integrally. The connection plate 80 includes an inner circumferential portion, an outer circumferential portion and a middle transition portion connecting the inner circumferential portion and the outer circumferential portion, which are arranged in a radial direction. Multiple axial through holes of the bearing inner race 21 extend and pass through the inner circumferential portion.

**[0054]** The structure of the connection plate 80 (i.e. the extending portion 310) shown in Figure 9B is similar to the structure of the connection plate 10, the structure of the connection plate 40 and the structure of the connection plate 60 described in the previous embodiments, a cross section of the connection plate 80 may be a shape of "H" or "Z". Other structures of the pitch apparatus are similar to the corresponding components of the pitch apparatus described in the previous embodiments, which will not be described herein.

**[0055]** The above five embodiments are described in conjunction with the drawings. It should be understood for those skilled in the art that structural characteristics described in one of the embodiments may also be applied to the other embodiments. The characteristics in the different embodiments may be mutually combined to form other embodiments in a case that there is no conflict among the characteristics. For example, in the embodiment shown in Figure 8B, the manner that the outer circumferential surface of the blade root is provided with the groove for preventing ta displacement of the transmission belt in the axial direction, may also be applied to other components apparently, such as pitch plates and extending portions according to the other embodiments.

**[0056]** The pitch apparatus in the present disclosure may be applied to the wind turbine, therefore, a wind turbine having the pitch apparatus is provided in the present disclosure.

**[0057]** In a case that the blades have a same specification, the blades have a same bending moment. Reference is made to Figures 1 and 2, since the blade 6 is connected to the bearing outer race 22 of the pitch bearing 2 in the conventional technology, in the case that the blades have the same specification, the size of the pitch bearing 2 is small. Accordingly, the diameter distribution of the pitch bearing and hub connection bolt 7, the pitch diameter of the bearing steel ball, the diameter of the transmission belt are also small. Since the load is proportional to the bending moment and inversely proportional to the pitch diameter, the load on the steel ball and the load on the bolt are large in a case of the same bending moment, so that the pitch bearing 2 is subjected to a large pitch load in a process of the blade pitch. Therefore, components such as the bolts of the pitch bearing 2 that are connected with the hub 1 and the ball of the pitch bearing 2 are all subjected to a large load, which may easily cause a damage to the pitch bearing 2 itself and the components in the pitch bearing.

**[0058]** According to the pitch apparatus of the wind turbine and the wind turbine having the pitch apparatus of the embodiment of the present disclosure, in a case that the blades have a same specification, by connecting the blade to the bearing inner race, a size of the pitch bearing can be increased accordingly, a pitch diameter of the bolt increases accordingly, the number of bolts increases, and a distribution diameter of the transmission element increases, so that an anti-load capacity of the blade root increases and a load on a single bolt and a load on the bearing roller decrease.

**[0059]** Specifically, according to the pitch apparatus of the wind turbine provided in the embodiment of the present disclosure, a load level of an ultimate bending moment for a blade root increases, a safety factor of the pitch bearing and a safety factor of the connection bolt increase, a safety factor of the pitch bearing inner race, a safety factor of the pitch bearing outer race and a safety factor of the transmission element increase and fracture failure risks of the pitch bearing and the transmission belt are reduced.

**[0060]** The above embodiments are only exemplary and are not intended to limit this disclosure. It should be understood by those skilled in the art that many modifications may be made to the embodiments of the disclosure without departing from the principles of the disclosure. The scope of the present disclosure is defined by the claims.

## Claims

1. A pitch apparatus applied in a wind turbine, wherein the wind turbine comprises a wheel hub (1) and a plurality of blades (6);

   wherein the pitch apparatus comprises:

   a pitch bearing (2);
   a transmission element;
   a connection plate (10, 40); and

a driving mechanism (4) for driving the transmission element;

wherein the pitch bearing (2) comprises:

a bearing inner race (21); and
a bearing outer race (22);

wherein the bearing inner race (21) is fixedly connected to the blade (6), the bearing outer race (22) is fixedly connected to the wheel hub (1), the transmission element is driven by the driving mechanism (4), and drives the blade (6) and the bearing inner race (21) to rotate in relative to the wheel hub (1);
wherein the connection plate (10, 40) comprises the following elements arranged in a radial direction:

an inner circumferential portion (11, 41);
an outer circumferential portion (13, 43); and
a middle transition portion (12, 42) connecting the inner circumferential portion (11, 41) and the outer circumferential portion (13, 43),
wherein the transmission element is arranged on an outer circumferential surface of the connection plate (10, 40), and an axial thickness of the middle transition portion (12, 42) is less than an axial thickness of the outer circumferential portion (13, 43), **characterized in that** the connection plate (10) is arranged between the bearing inner race (21) and the blade (6); or
the connection plate (40) is arranged on a periphery of the blade root of the blade (6), wherein the connection plate (40) is ring-shaped or partially ring-shaped, and the inner circumferential portion (41) is fixed to the periphery of the blade root of the blade (6).

**2.** The pitch apparatus according to claim 1, wherein the inner circumferential portion (11) is a ring and comprises a plurality of first axial through holes (14) arranged in a circumferential direction; wherein the bearing inner race (21) comprises a plurality of second axial through holes corresponding to the plurality of first axial through holes (14); wherein a bearing inner race connection bolt (8) is fastened to the blade (6) through one of the plurality of second axial through holes and one of the plurality of first axial through holes (14) in the sequence listed.

**3.** The pitch apparatus according to claim 1, wherein the inner circumferential portion (41) is provided with a plurality of inserting projections (44) extending inwardly in the radial direction, the periphery of the blade root of the blade (6) is provided with a plurality of inserting grooves, the plurality of inserting projections (44) each is fixed into one of the plurality of inserting grooves.

**4.** The pitch apparatus according to claim 1, wherein the connection plate (40) consists of a plurality of arc-segment portions, a circumferential angle of the plurality of arc-segment portions each is less than or equal to 180°.

**5.** The pitch apparatus according to claim 1, wherein the connection plate (10, 40) comprises at least one of the following structural characteristics:

a plurality of lightening holes (15) is formed on the middle transition portion (12);
the outer circumferential portion (13) is ring-shaped or partially ring-shaped, or the outer circumferential portion (13) and the middle transition portion (12) is ring-shaped or partially ring-shaped; and
a toothed structure is formed on an outer circumferential surface of the outer circumferential portion (13, 43) of the connection plate (10, 40).

**6.** The pitch apparatus according to claim 1, wherein the connection plate (10, 40) is formed integrally with the blade (6).

**7.** The pitch apparatus according to claim 6, wherein the outer circumferential portion (13, 43) comprises an axially extending portion.

**8.** The pitch apparatus according to claim 1, wherein the connection plate (10, 40) is formed integrally with the bearing inner race (21).

**9.** The pitch apparatus according to claim 8, wherein the outer circumferential portion (13, 43) comprises an axially extending portion.

**10.** A wind turbine, comprising the pitch apparatus according to any one of claims 1 to 9.

**Patentansprüche**

**1.** Pitch-Vorrichtung, die in eine Windturbine eingesetzt wird, wobei die Windturbine eine Radnabe (1) und eine Mehrzahl von Schaufeln (6) aufweist;

wobei die Pitch-Vorrichtung aufweist:

ein Pitchlager (2);
ein Übertragungselement;
eine Verbindungsplatte (10, 40); und

einen Antriebsmechanismus (4) zum Antreiben des Übertragungselements;

wobei das Pitchlager (2) aufweist:

einen Lagerinnenring (21); und
einen Lageraußenring (22);

wobei der Lagerinnenring (21) fest mit der Schaufel (6) verbunden ist, der Lageraußenring (22) fest mit der Radnabe (1) verbunden ist, das Übertragungselement durch den Antriebsmechanismus (4) angetrieben wird und die Schaufel (6) und den Lagerinnenring (21) relativ zu der Radnabe (1) in Drehung versetzt;
wobei die Verbindungsplatte (10, 40) die folgenden in einer radialen Richtung angeordneten Elemente aufweist:

einen Innenumfangsabschnitt (11, 41);
einen Außenumfangsabschnitt (13, 43); und
einen mittleren Übergangsabschnitt (12, 42), der den Innenumfangsabschnitt (11, 41) und den Außenumfangsabschnitt (13, 43) verbindet,

wobei das Übertragungselement auf einer Außenumfangsfläche der Verbindungsplatte (10, 40) angeordnet ist und eine axiale Dicke des mittleren Übergangsabschnitts (12, 42) kleiner ist als eine axiale Dicke des Außenumfangsabschnitts (13, 43),
**dadurch gekennzeichnet, dass**
die Verbindungsplatte (10) zwischen dem Lagerinnenring (21) und der Schaufel (6) angeordnet ist; oder
die Verbindungsplatte (40) an einem Umfang des Schaufelfußes der Schaufel (6) angeordnet ist,
wobei die Verbindungsplatte (40) ringförmig oder teilweise ringförmig ist und der Innenumfangsabschnitt (41) an dem Umfang des Schaufelfußes der Schaufel (6) fixiert ist.

**2.** Pitch-Vorrichtung nach Anspruch 1, wobei der Innenumfangsabschnitt (11) ein Ring ist und eine Mehrzahl erster axialer Durchgangslöcher (14) aufweist, die in einer Umfangsrichtung angeordnet sind; wobei der Lagerinnenring (21) eine Mehrzahl zweiter axialer Durchgangslöcher aufweist, die der Mehrzahl erster axialer Durchgangslöcher (14) entsprechen; wobei ein Lagerinnenring-Verbindungsbolzen (8) durch eines der Mehrzahl zweiter axialer Durchgangslöcher und eines der Mehrzahl erster axialer Durchgangslöcher (14) in der angegebenen Reihenfolge an der Schaufel (6) befestigt ist.

**3.** Pitch-Vorrichtung nach Anspruch 1, wobei der Innenumfangsabschnitt (41) mit einer Mehrzahl von Einsetzvorsprüngen (44) versehen ist, die sich in der radialen Richtung nach innen erstrecken, der Umfang des Schaufelfußes der Schaufel (6) mit einer Mehrzahl von Einsetznuten versehen ist und die Mehrzahl von Einsetzvorsprüngen (44) jeweils in einer der Mehrzahl von Einsetznuten befestigt sind.

**4.** Pitch-Vorrichtung nach Anspruch 1, wobei die Verbindungsplatte (40) aus einer Mehrzahl von Bogensegmentabschnitten besteht, ein Umfangswinkel der Mehrzahl von Bogensegmentabschnitten jeweils kleiner als oder gleich 180° ist.

**5.** Pitch-Vorrichtung nach Anspruch 1, wobei die Verbindungsplatte (10, 40) mindestens eine der folgenden Struktureigenschaften aufweist:

eine Mehrzahl von Erleichterungslöchern (15) auf dem mittleren Übergangsabschnitt (12) ausgebildet ist;
der Außenumfangsabschnitt (13) ringförmig oder teilweise ringförmig ist oder der Außenumfangsabschnitt (13) und der mittlere Übergangsabschnitt (12) ringförmig oder teilweise ringförmig sind; und
eine gezahnte Struktur auf einer Außenumfangsfläche des Außenumfangsabschnitts (13, 43) der Verbindungsplatte (10, 40) ausgebildet ist.

**6.** Pitch-Vorrichtung nach Anspruch 1, wobei die Verbindungsplatte (10, 40) einstückig mit der Schaufel (6) ausgebildet ist.

**7.** Pitch-Vorrichtung nach Anspruch 6, wobei der Außenumfangsabschnitt (13, 43) einen sich axial erstreckenden Abschnitt aufweist.

**8.** Pitch-Vorrichtung nach Anspruch 1, wobei die Verbindungsplatte (10, 40) einstückig mit dem Lagerinnenring (21) ausgebildet ist.

**9.** Pitch-Vorrichtung nach Anspruch 8, wobei der Außenumfangsabschnitt (13, 43) einen sich axial erstreckenden Abschnitt aufweist.

**10.** Windturbine, aufweisend die Pitch-Vorrichtung nach einem der Ansprüche 1 bis 9.

**Revendications**

**1.** Dispositif de réglage de pas utilisé dans une éolienne, l'éolienne comprenant un moyeu (1) et une pluralité de pales (6) ;

le dispositif de réglage de pas comprenant :

un palier de réglage de pas (2) ;
un élément de transmission ;
une plaque de liaison (10, 40) ; et
un mécanisme d'entraînement (4) permettant d'entraîner l'élément de transmission ;

le palier de réglage de pas (2) comprenant :

un chemin de roulement interne (21) de palier ; et
un chemin de roulement externe (22) de palier ;

le chemin de roulement interne (21) du palier étant relié fixe à la pale (6), le chemin de roulement externe (22) du palier étant relié fixe au moyeu (1), l'élément de transmission étant entraîné par le mécanisme d'entraînement (4), et entraînant la pale (6) et le chemin de roulement interne (21) du palier en rotation par rapport au moyeu (1) ;
la plaque de liaison (10, 40) comprenant les éléments suivants disposés dans un sens radial :

une partie circonférentielle interne (11, 41) ;
une partie circonférentielle externe (13, 43) ; et
une partie de transition intermédiaire (12, 42) reliant la partie circonférentielle interne (11, 41) et la partie circonférentielle externe (13, 43),

l'élément de transmission étant disposé sur une surface circonférentielle externe de la plaque de liaison (10, 40), et une épaisseur axiale de la partie de transition intermédiaire (12, 42) étant inférieure à une épaisseur axiale de la partie circonférentielle externe (13, 43),
**caractérisé en ce que**
la plaque de liaison (10) est disposée entre le chemin de roulement interne (21) du palier et la pale (6) ; ou
la plaque de liaison (40) est disposée sur une périphérie du pied de pale de la pale (6),
la plaque de liaison (40) présentant une forme annulaire ou partiellement annulaire, la partie circonférentielle interne (41) étant fixée à la périphérie du pied de pale de la pale (6).

**2.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la partie circonférentielle interne (11) est un anneau et comprend une pluralité de premiers trous traversants axiaux (14) disposés dans un sens circonférentiel ; dans lequel le chemin de roulement interne (21) du palier comprend une pluralité de second trous traversants axiaux correspondant à la pluralité de premiers trous traversants axiaux (14) ; dans lequel un boulon de liaison (8) du chemin de roulement interne du palier est fixé à la pale (6) par l'intermédiaire d'un trou parmi la pluralité de seconds trous traversants axiaux et d'un trou parmi la pluralité de premiers trous traversants axiaux (14) dans la séquence indiquée.

**3.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la partie circonférentielle interne (41) est munie d'une pluralité de saillies d'insertion (44) s'étendant vers l'intérieur dans le sens radial, la périphérie du pied de pale de la pale (6) est munie d'une pluralité de rainures d'insertion, et chaque saillie parmi la pluralité de saillies d'insertion (44) est fixée dans une rainure parmi la pluralité de rainures d'insertion.

**4.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la plaque de liaison (40) consiste en une pluralité de parties de segment d'arc, un angle circonférentiel de chaque partie parmi la pluralité de parties de segment d'arc étant inférieur ou égal à 180°.

**5.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la plaque de liaison (10, 40) comprend au moins l'une des caractéristiques structurelles suivantes :

une pluralité de trous d'allègement (15) est formée sur la partie de transition intermédiaire (12) ;
la partie circonférentielle externe (13) présente une forme annulaire ou partiellement annulaire, ou la partie circonférentielle externe (13) et la partie de transition intermédiaire (12) présentent une forme annulaire ou partiellement annulaire ; et
une structure dentée est formée sur une surface circonférentielle externe de la partie circonférentielle externe (13, 43) de la plaque de liaison (10, 40).

**6.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la plaque de liaison (10, 40) est formée en une seule pièce avec la pale (6).

**7.** Le dispositif de réglage de pas selon la revendication 6, dans lequel la partie circonférentielle externe (13, 43) comprend une partie s'étendant axialement.

**8.** Le dispositif de réglage de pas selon la revendication 1, dans lequel la plaque de liaison (10, 40) est formée en une seule pièce avec le chemin de roulement interne (21) du palier.

**9.** Le dispositif de réglage de pas selon la revendication

8, dans lequel la partie circonférentielle externe (13, 43) comprend une partie s'étendant axialement.

**10.** Éolienne comprenant le dispositif de réglage de pas selon l'une quelconque des revendications 1 à 9.

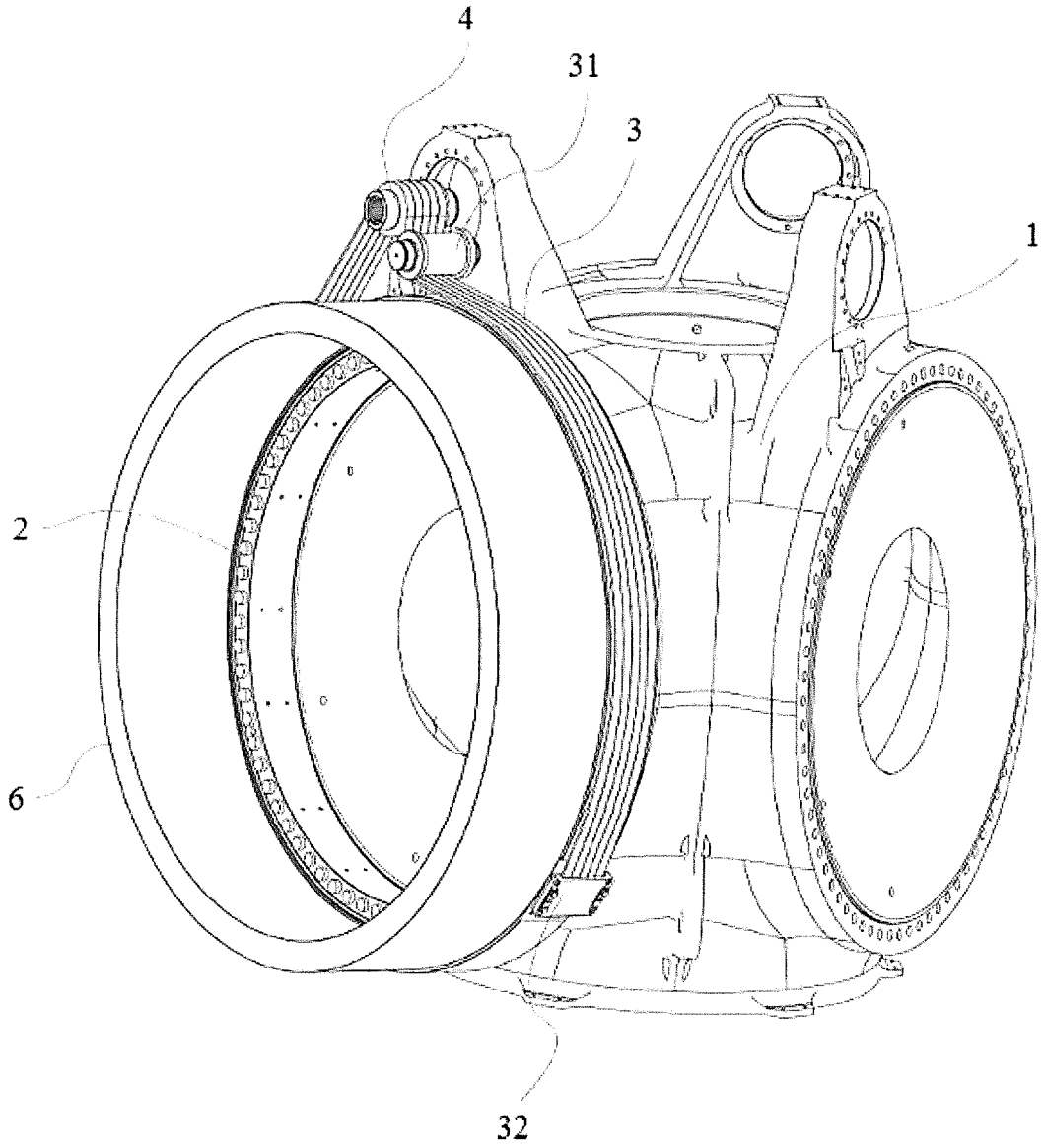


**Figure 1**

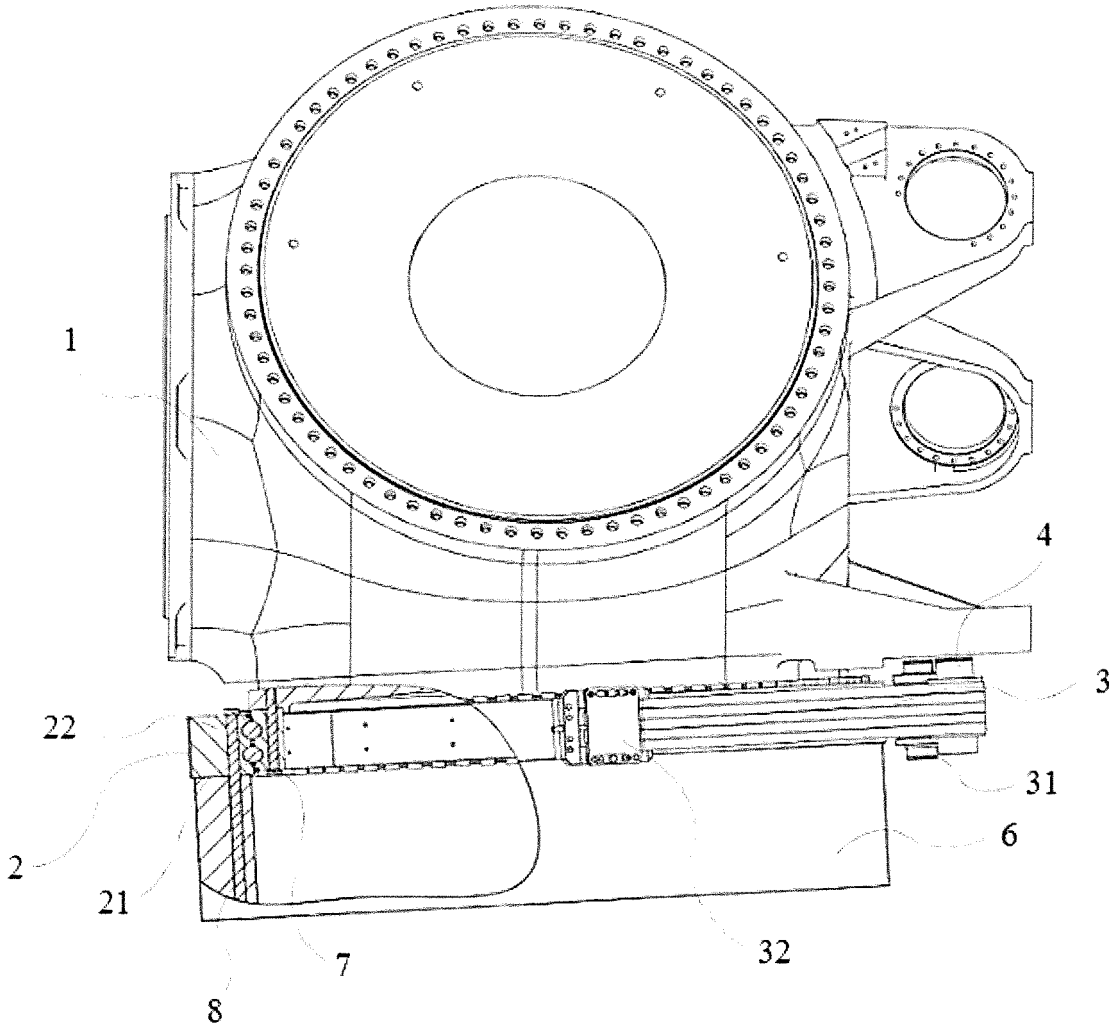


**Figure 2**

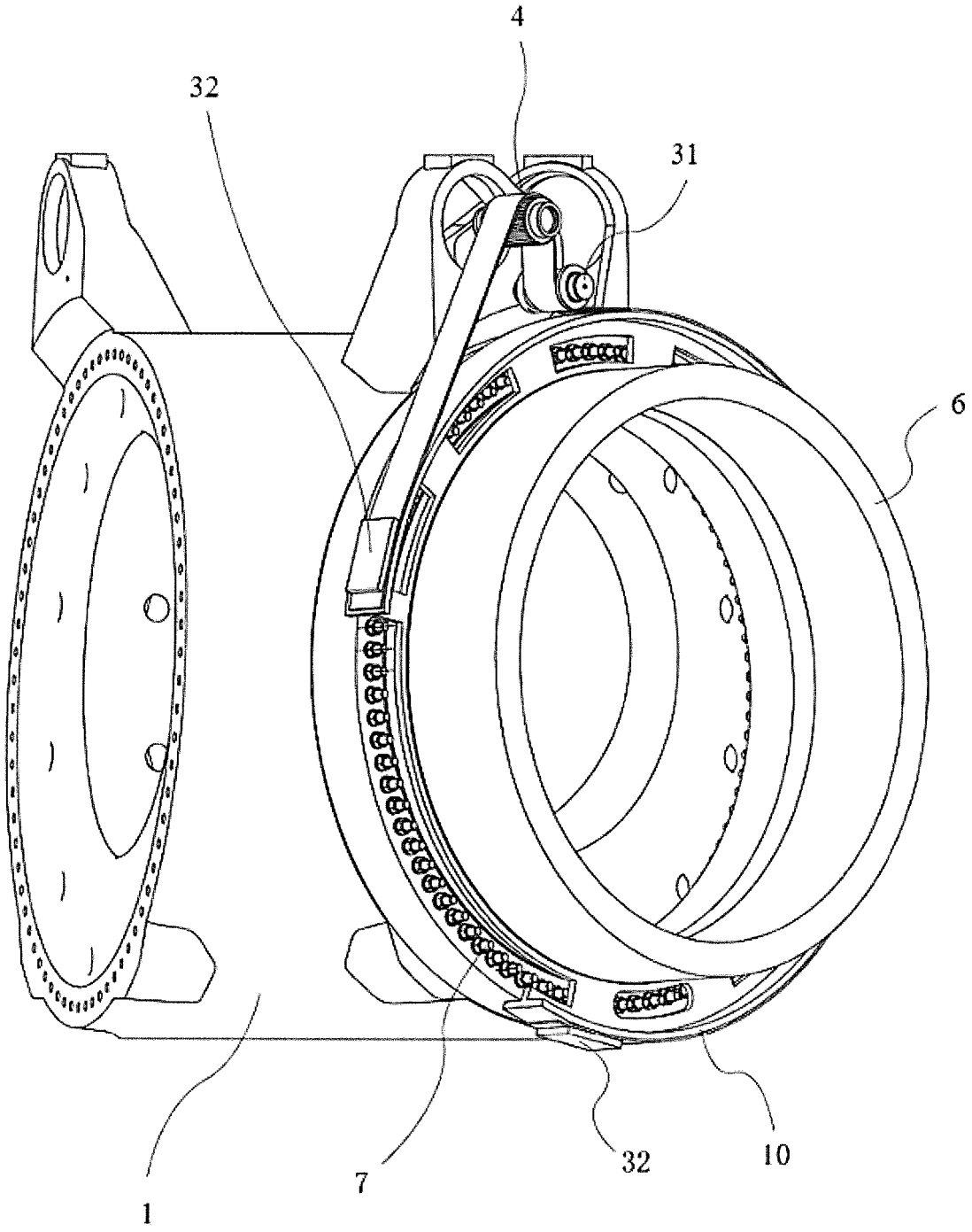


Figure 3

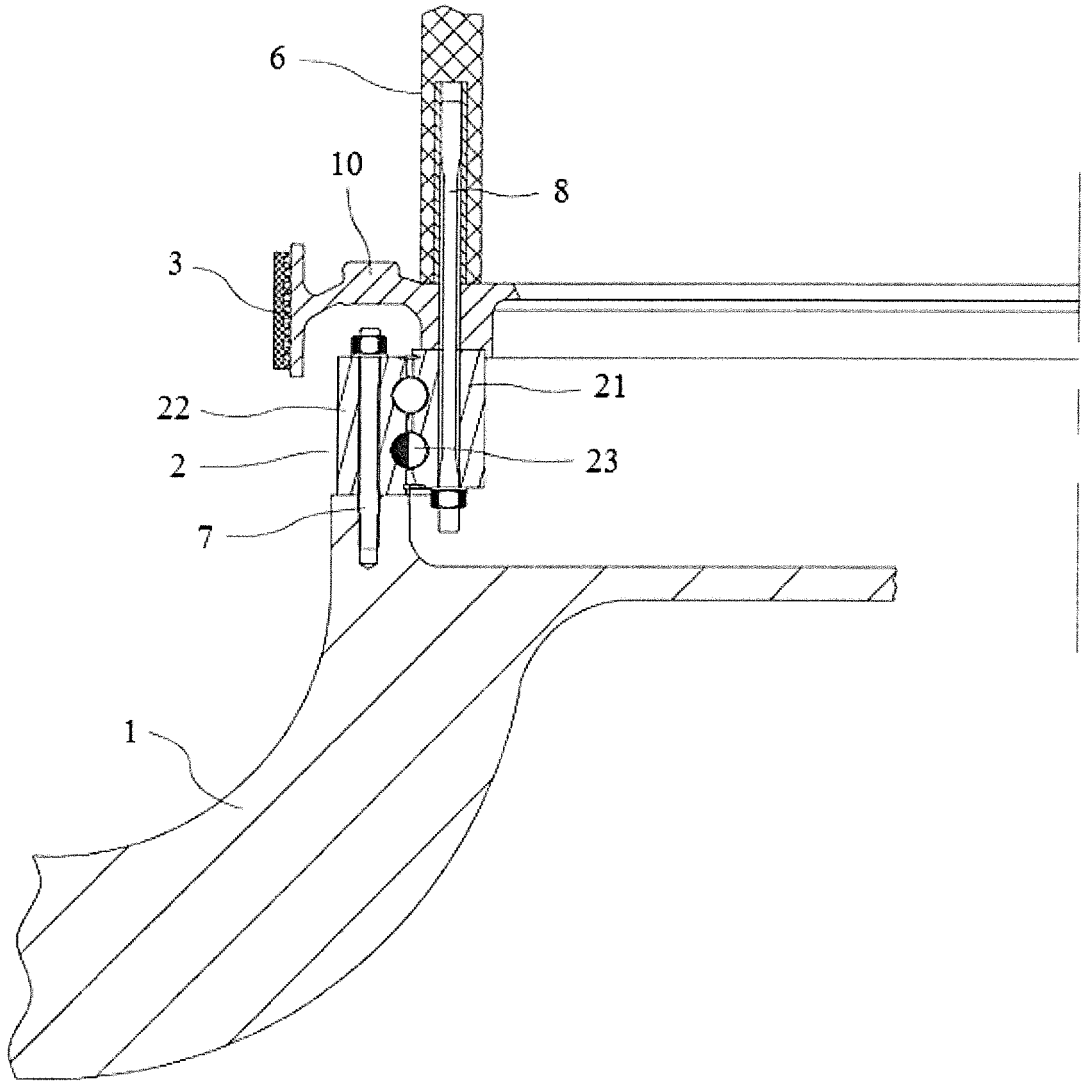


**Figure 4**

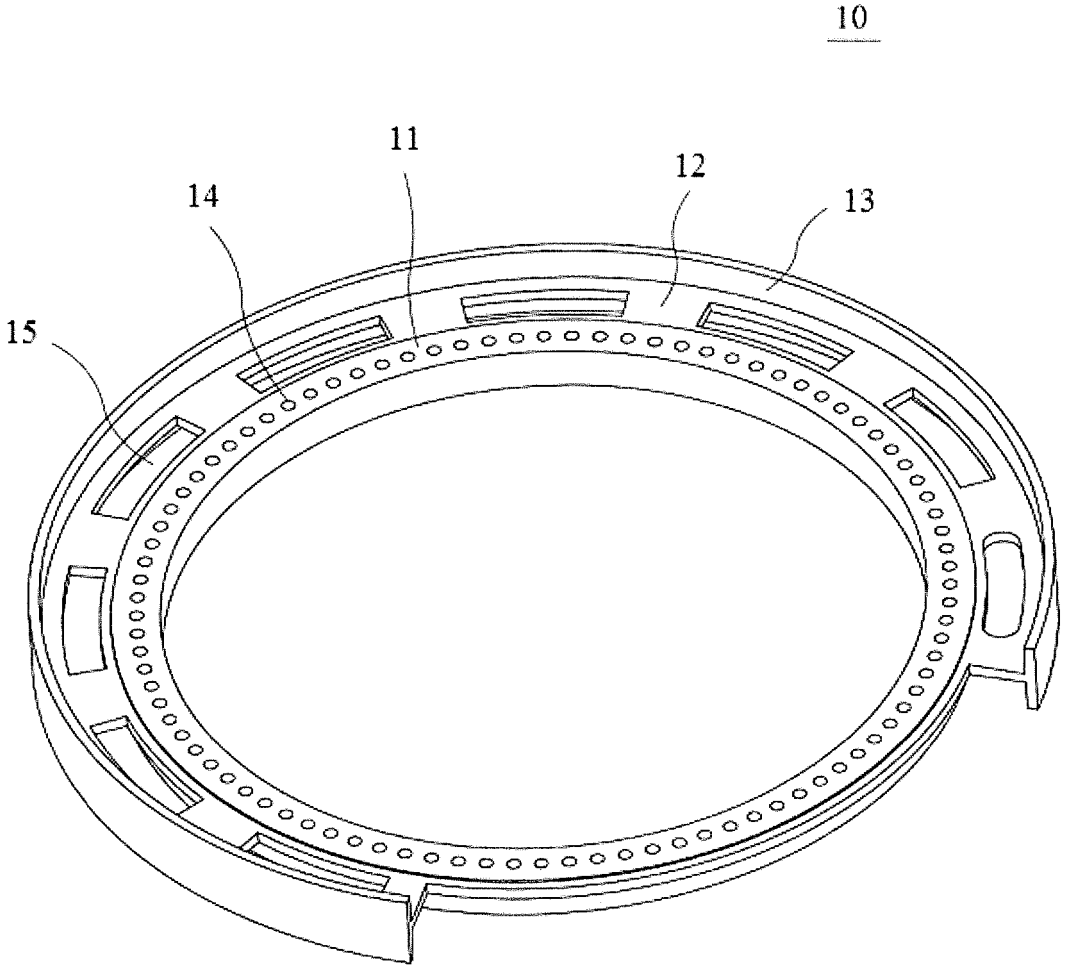


**Figure 5**

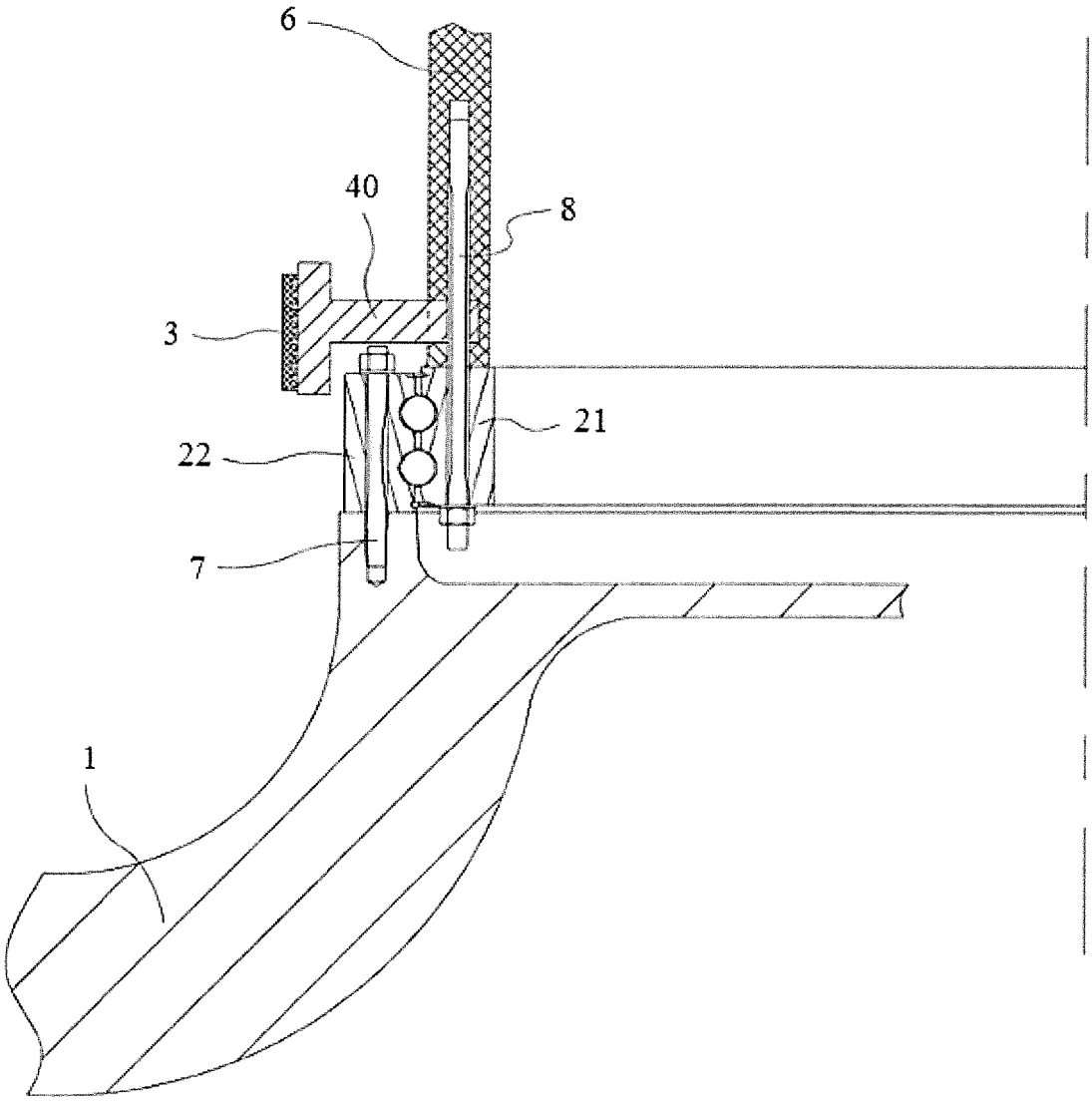


Figure 6A

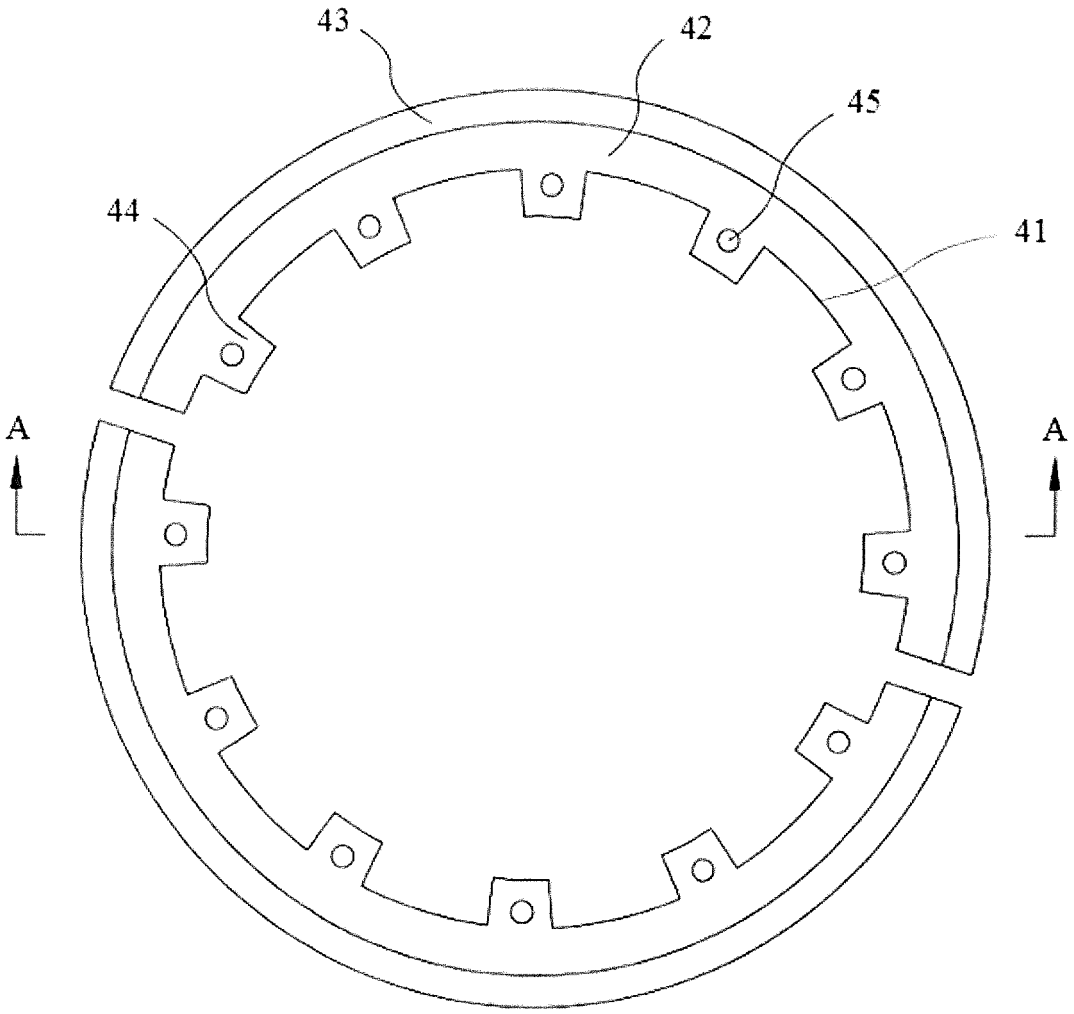


Figure 6B

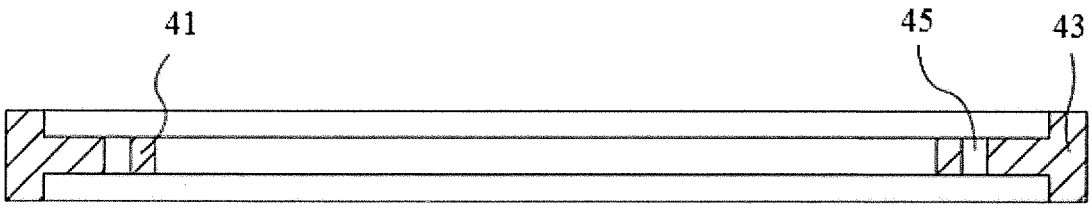


Figure 6C

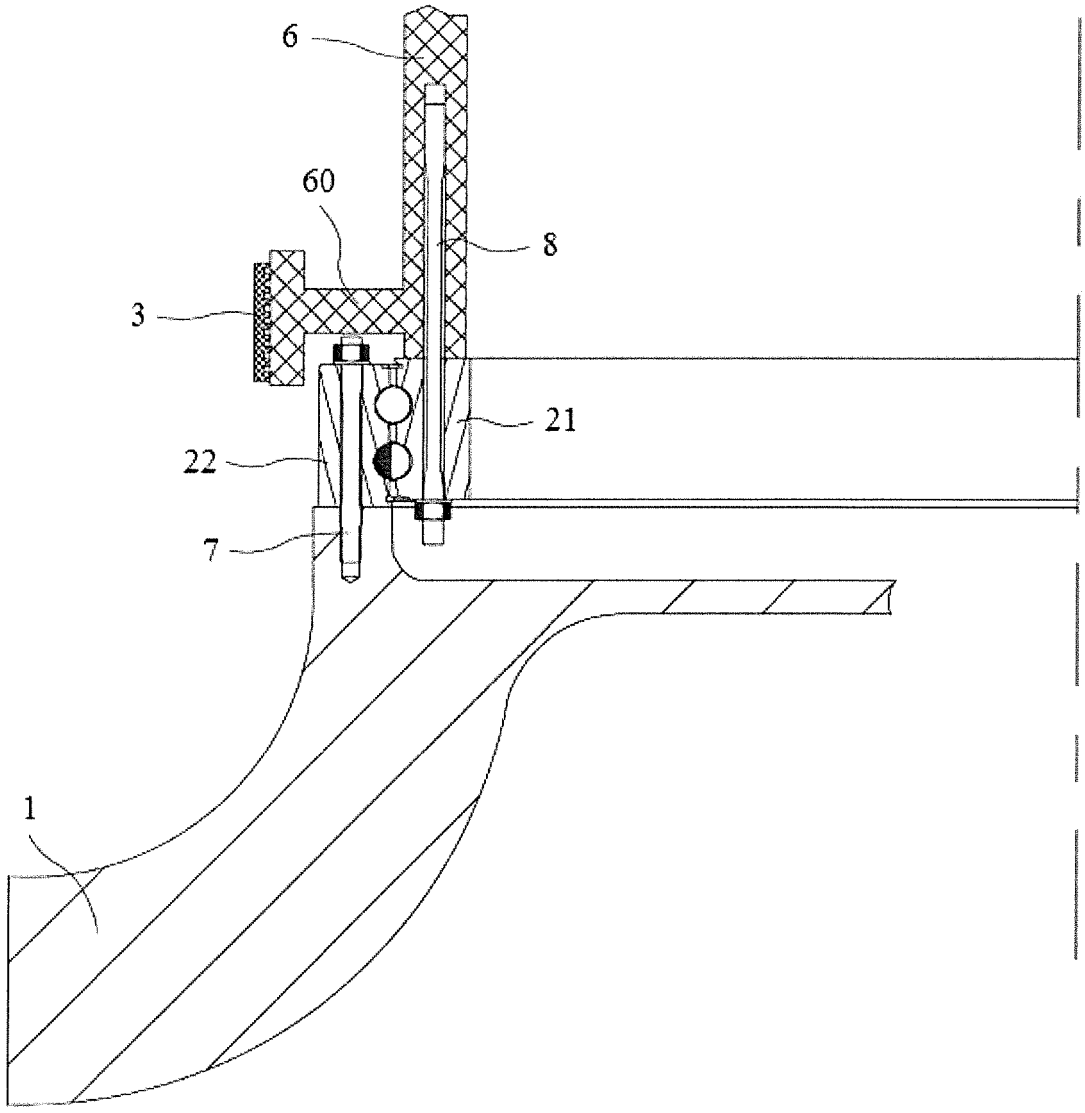


Figure 7A

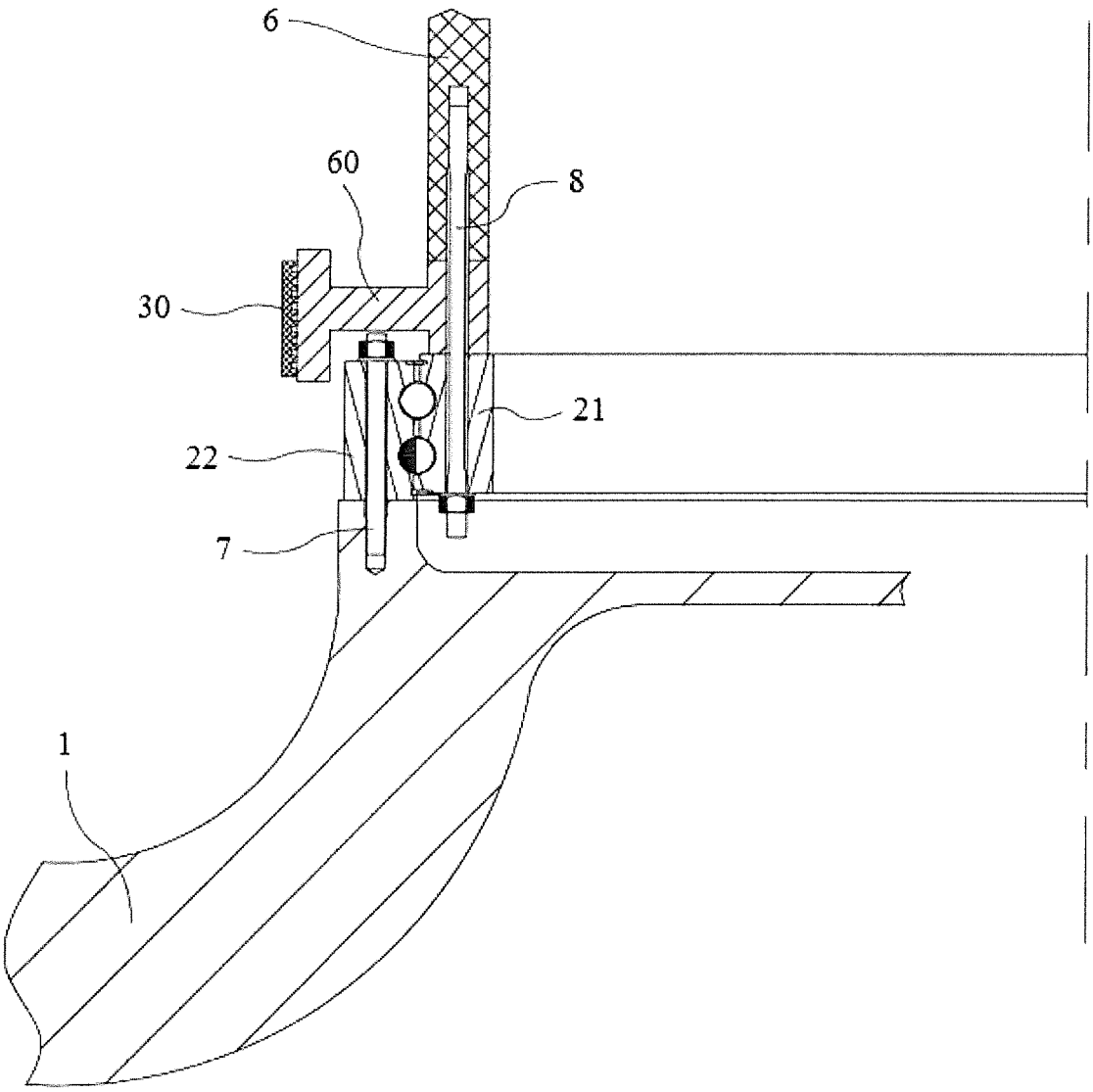


**Figure 7B**

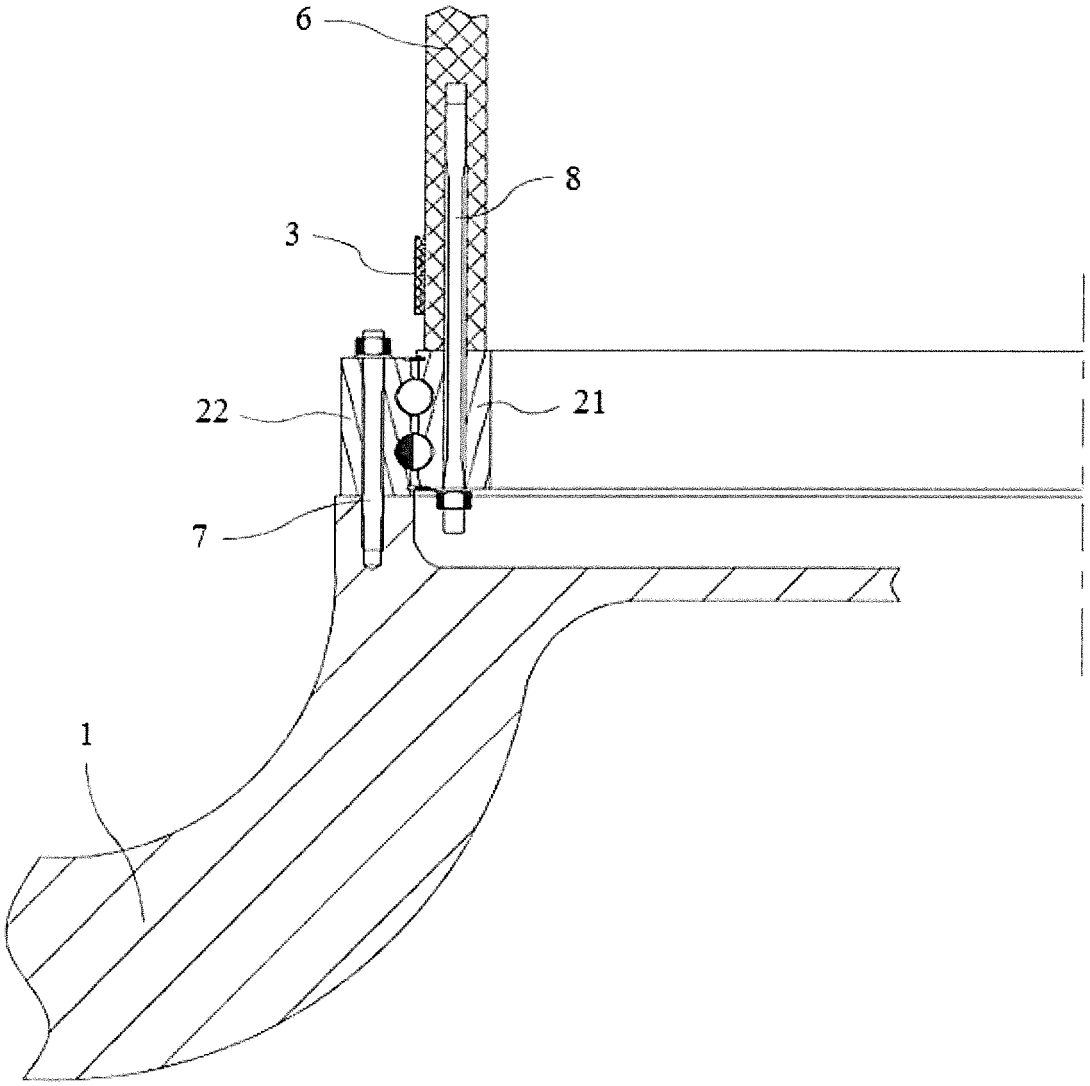


Figure 8A

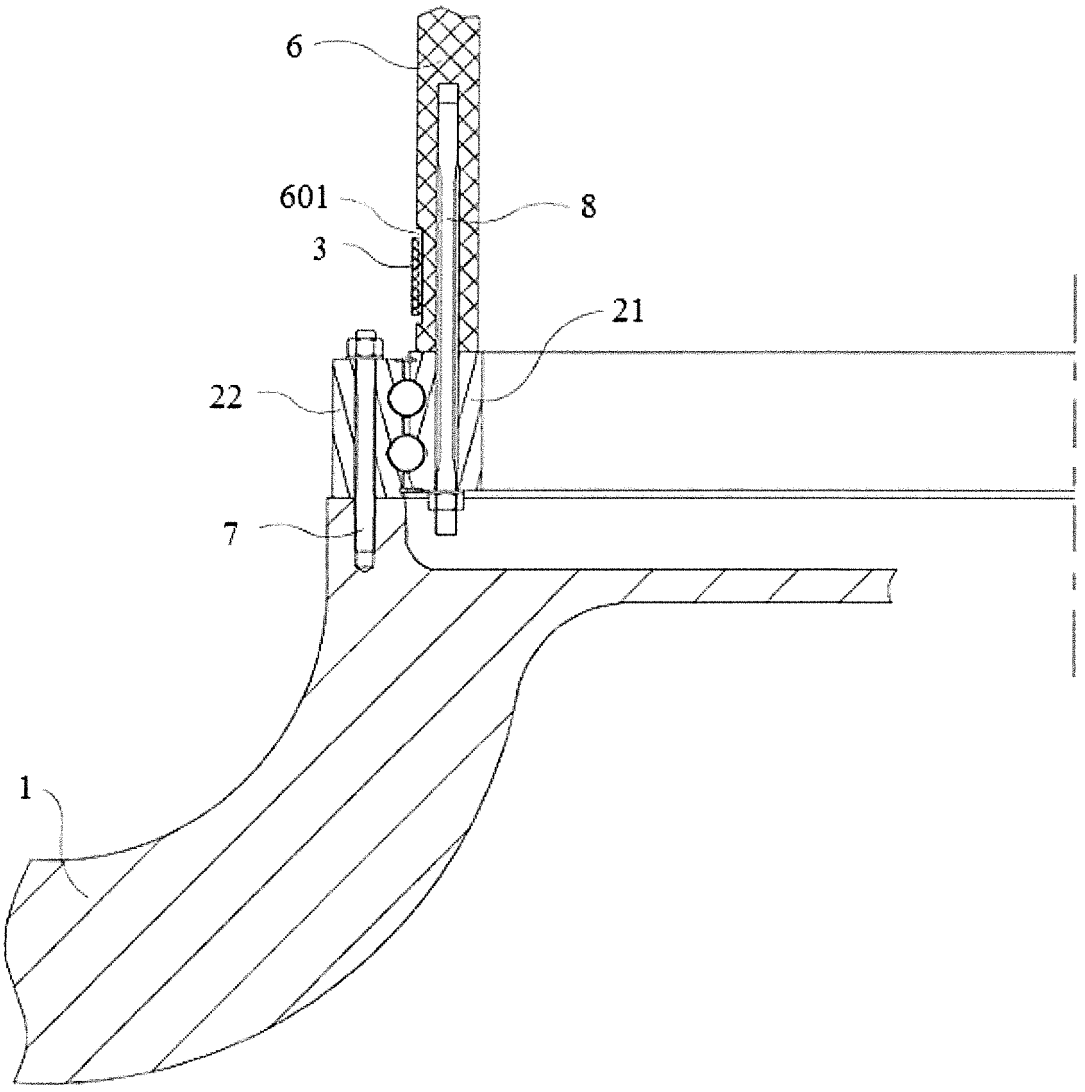


**Figure 8B**

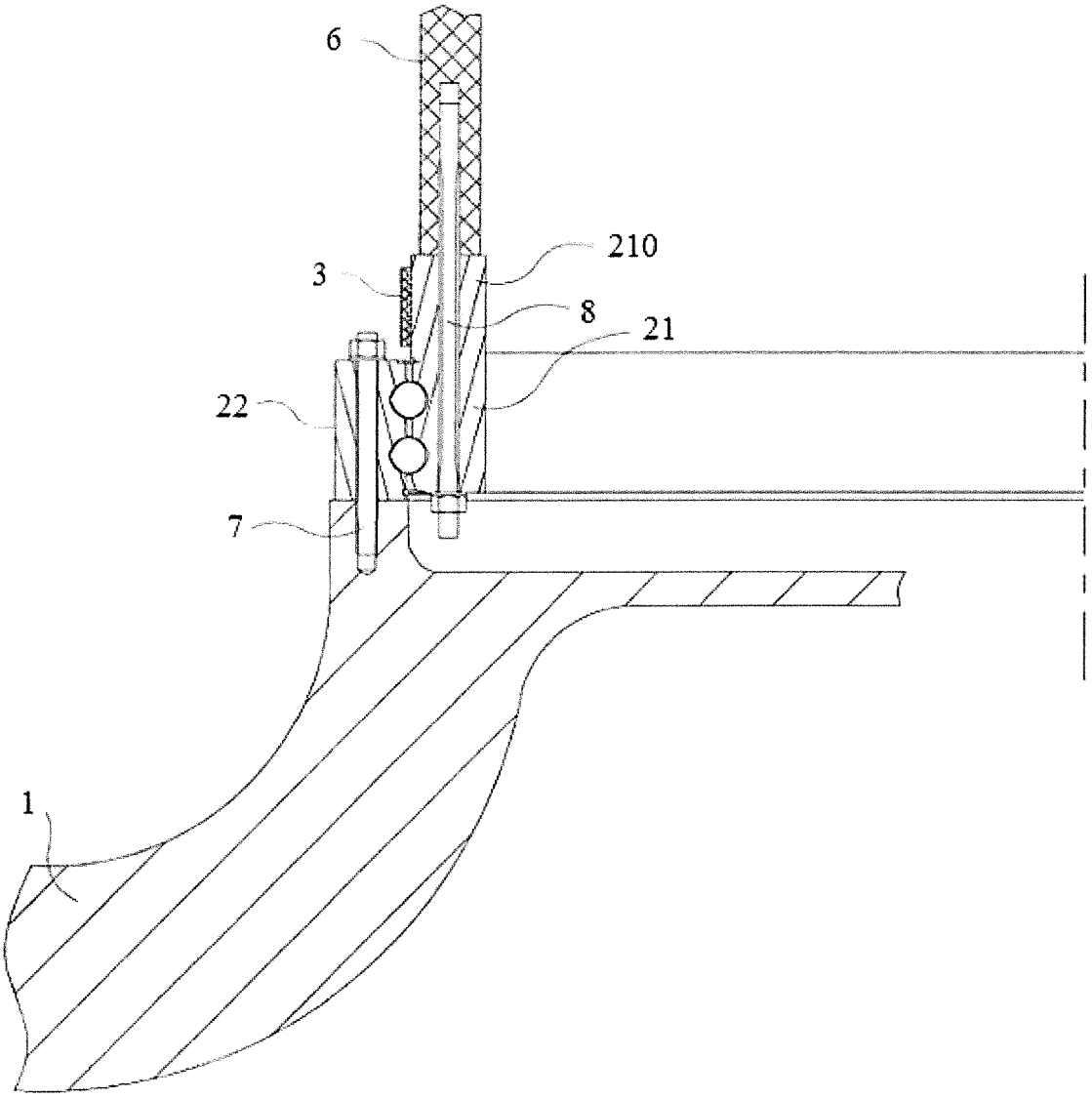


Figure 9A

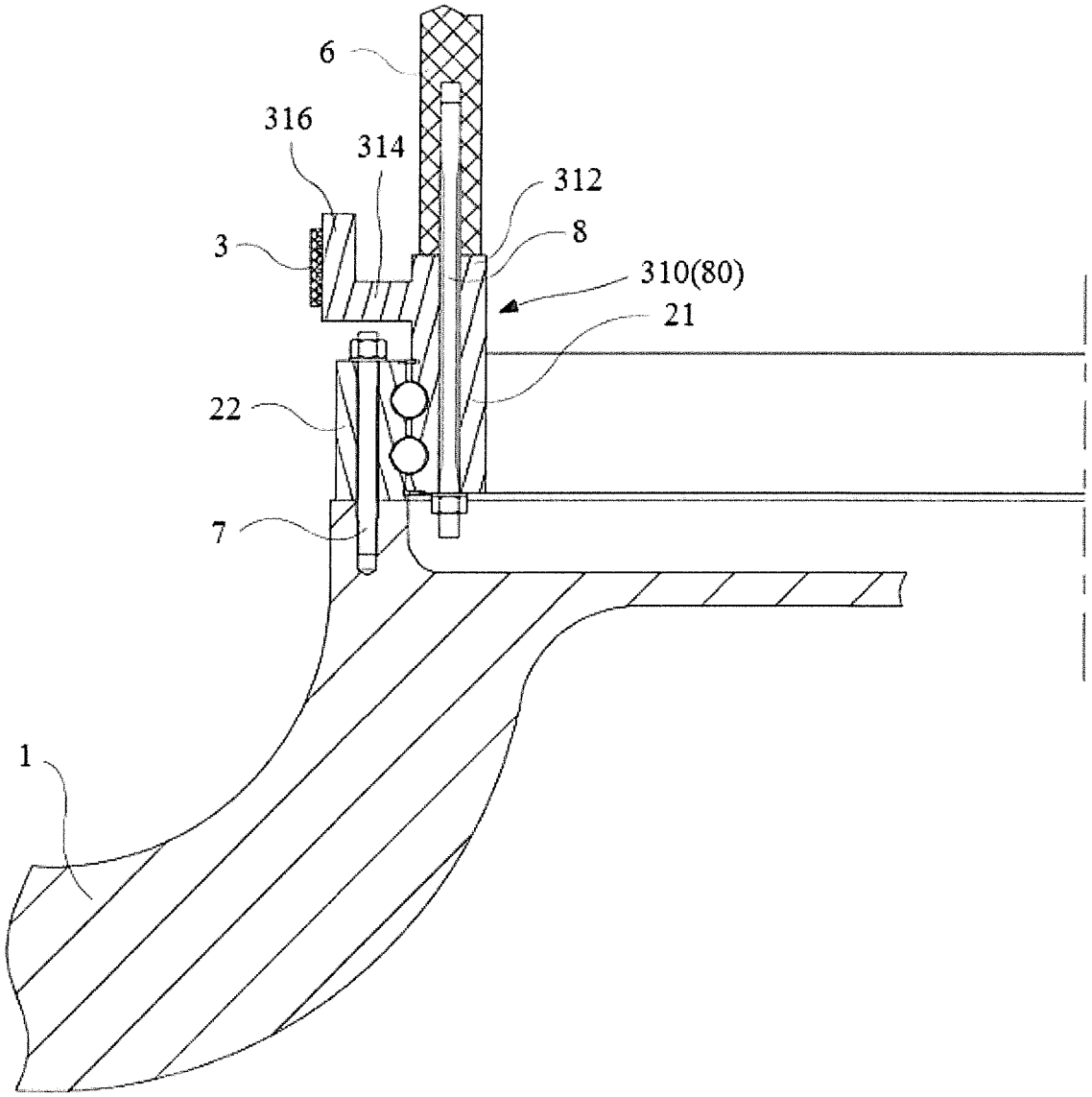


**Figure 9B**

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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